MDE Product Development Team
February FY14 Monthly Report
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Executive Summary

Task 1: Improve turbulence guidance from NWP forecasts

- **RAPv2 became operational at NCEP at 12z Tuesday 25 February 2014; transition from RAPv1 went smoothly (see http://rapidrefresh.noaa.gov)**
- RAPv2 webinar given to NWS forecasters in February (at 2 different times) - **http://ruc.noaa.gov/pdf/RAPv2-NWSwebinar-18feb2014-FINAL.pdf**
- RAP/HRRR presentation at December 2013 annual NCEP Model Production Suite Review, available at **http://ruc.noaa.gov/pdf/NCEP_PSR_2013_RAP_FINAL_v5.pdf**
- Three real-time parallel RAP cycles (with extensive verification of each toward RAP version 3) running on Zeus to evaluate further likely enhancements to RAP data assimilation / model system for spring 2014 code freeze and to be implemented at NCEP in 2015.
- Likely near-final RAPv3 analysis, model and post-processing configuration now running in RAP-primary at GSD since 12 March 2014.
- RAPv3 giving greater weight to ensemble covariances in GSI ensemble-hybrid analysis, use of background 2-m forecast dew point and temperature instead of 8m, WRFv3.5.1 model code with upgrades to RRTMG radiation, RUC LSM upgrades, further modification to MYNN surface layer and PBL, Grell-Freitas deep and shallow convection and v3.5.1 Thompson microphysics, as well as enhancements to post-processing.
- NCEP making continued progress on NAM and NAM-nest

Task 2: Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

- Continued work to finalize the HRRR configuration (HRRRv1) on the NCEP WCOSS computer, focusing on optimization to fit run within an hour and reduce latency of output, especially for earliest forecast hours. NCEP implementation date tentatively set for 15 July or 29 July 2014.
- Significant upgrade package installed in GSD real-time RAP/HRRR for 2014 warm season evaluation. Package highlights includes improved physics. HRRRv2 is showing improved convective storm forecast skill, especially with less over-forecasting. Additional testing on threshold and strength of 3-km radar diabatic heating ongoing.
- Hourly and 15-min RTMA surface analyses continue to run in real-time with grids available on ftp for external users.
- Preliminary testing of HRRR application of GSI global ensemble-based hybrid assimilation.

Task 3: Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

- Latest version of Grell-Freitas cumulus scheme in RAP deemed fit to replace old G3 scheme for RAPv3.
- RAP-primary and RAP-dev cycles now all running with likely RAPv3 physics configuration.
- Good progress in substantially reducing cold nighttime bias over snow cover Implementation of this physics configuration in RAP-primary 12 March 2014; expected in RAPv3 at NCEP in winter 2014-15~~)~~
- RAPv2 updated physics configuration including updated Thompson cloud microphysics, and MYNN-Olson boundary-layer mixing (better winds near surface including terminals) running operationally at NCEP as part of the 25 February 2014 implementation.

Task 4: Develop convection-ATM-specific improvements to guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA

- Real-time, frozen RAPv2 (matching NCEP RAPv2)/HRRR system continues to run successfully with gridded field dissemination into winter 2013-14 although CoSPA officially shut down on 1 Nov 2013.
- HRRR "failover" capability to use feed from Zeus instead of Jet during Jet downtime continued to work.
- GSD plans for HRRRv2 follows physics changes for RAPv3, and a plan to be implemented on Jet and Zeus by early April 2014 and at NCEP in 2015.

Task 1: Improve turbulence guidance from NWP forecasts

Improving turbulence forecast quality involves efforts to improve initial conditions for the RAP and NAM (and HRRR and NAM Nest models) and to improve the models (WRF-Advanced Research WRF (ARW)-RAP and NOAA Environmental Modeling System (NEMS)- Nonhydrostatic Multi-scale Model – B (NMMB)).
Tasks will include:

- Continuing evaluation of RAPv2 toward early 2014 implementation at NCEP, incorporating changes developed in 2012 and early 2013
- Development of RAPv3 toward 2014 implementation at ESRL and subsequent implementation at NCEP
- Collaborating on developing and testing best approaches for use of hybrid/EnKF/3DVAR data assimilation within common GSI coding structure.

ESRL

Regarding the operational NCEP RAP

The operational RAP (RAPv1) was upgraded to RAPv2 as scheduled at 1200 UTC Tuesday 25 February 2014. The RAPv2 has run well since its implementation except for a post-processing error at NCEP that affected the downward shortwave radiation at the surface for CONUS 130 grids only. An emergency fix for this is forthcoming. For all of 2014 prior to the RAPv2 implementation, the RAPv1 ran without any technical problems, including in the post processing.

The RAP web page **http://rapidrefresh.noaa.gov** is updated with information on the operational RAPv2 configuration. A link to the RAPv2 Technical Implementation Notice is there also. A webpage on RAP output grids from NCEP is at **http://ruc.noaa.gov/rr/RAP-NCEP-output-grids.html**.

RAPv3 model testing

Testing of candidate configurations for RAPv3 is nearing completion thanks to an intensive effort by the RAP development team and judicious use of the 3 development cycles on Zeus plus retrospective testing of candidate changes for improved summer performance. On 12 March the near-final RAPv3 configuration was put into the RAP-primary cycle at GSD. The following summarizes major changes from RAPv2 for analysis, model and post-processing for this configuration.

Analysis (data assimilation)

- Gridpoint Statistical Interpolation (GSI) code updated to recent NCEP repository release
- Weighting between the ensemble-derived and static (3dVAR) covariances changed from 50%-50% to 75% ensemble – 25% static in the GSI hybrid-variational analysis. Giving greater weight to the (GFS) ensemble-derived covariances improved performance slightly in the first several hours of the forecast.
- Radiance bias correction is now cycled rather than being specified as a constant (see paragraph on this area regarding GSD effort from Haidao Lin below)
- Three improvements to the GSI cloud / hydrometeor analysis
    - Correction to formula for conservation of virtual potential temperature when cloud added or removed. *This important change came as a result of feedback from the Storm Prediction Center concerning RAP performance on 17 November 2013.*
    - Impose limit of 100% saturation
    - Correct specification of rain-number concentration
- Capability to use slightly modified background for water vapor in hybrid-variational analysis.
- Snow building / trimming updated to add snow over generally smaller areas, but in larger amounts where it is added, based on IMS snow and ice analysis. Ensure skin temperature and temperature in snow is ≤ 272K wherever snow is added.

Mode

- Update to WRFv3.5.1 from 3.4.1. This includes a slightly revised version of the Thompson microphysics. The v3.5.1 versions of the MYNN PBL and the RUC LSM have received further upgrades as discussed here and under Task 3.

- Switch from Goddard short wave and RRTM long-wave radiation to RRTMG for both short and long wave, and reduce frequency of calls to radiation to once every 20min from every 10min. (see Task 3).
- Enabled "swint" option to recompute solar radiation based on current-forecast-time solar zenith angle at time steps when short-wave radiation not called.
- RUC LSM upgrades for improved treatment of albedo over partial snow cover as well as other details in treatment of snow (Task 3).
- Replace the Grell WRFv3.2.1 G3 deep and shallow cumulus scheme by the Grell-Frietas (G-F) deep and shallow cumulus scheme with radiation feedback (see Task 3).
- Updates to mitigate cold bias over snow (see Task 3)
    - Increased thickness of top snow layer in RUC LSM
    - Reduced assumed value of exchange coefficient under stable stratification when 2-m temperature and mixing ratio are diagnosed from values at lowest model level (~ 8m).
    - Decrease of thermal roughness length over snow under very stable conditions in MYNN surface-layer scheme.
- Various changes to MYNN PBL scheme to address tendency for warm bias at the surface during afternoon and evening during warm season (discussed in past MDE reports) and to improve coupling with G-F shallow cumulus scheme.
- Switch to hypsometric_opt = 2 in model namelist, together with NCAR bug fix in for this option (see FY2014Q1 MDE report for more details on this change, which was introduced to prevent occasional crashing along lateral boundaries. We also plan to retest the late-2013 crash cases in the NCEP-NCO parallel RAPv2 with the bug-free hypsometric_opt = 2 after removal of the terrain modifications near the lateral boundaries introduced in late 2013, but using the blended WPS geogrid terrain option (WRF terrain blended with external model, in the case of RAP, the GFS) near the boundaries.

Post-processing

- Added Direct Normal Incident solar radiation and whole-sky diffuse solar radiation to model output.
- Added capability to output 2-m dew point diagnosed from lowest model layer dew point and surface latent-heat flux.
- Introduced check to ensure that output 2-m dew point is not higher than output 2-m temperature.
- Relaxed restriction on ice pellets at lowest model level in precipitation-type algorithm (allows greater areal coverage of ice-pellet precipitation type in output precipitation-type fields).
- Bug fixes for binary I/O, very small hydrometeor mixing ratios, and for small differences between lowest two model layer-interface pressures.
- Proper calculation of 0-h 1km AGL and 4km AGL reflectivity.

The above configuration for analysis, model and post-processing was ported to the RAP-primary on 12 March, replacing the RAPv2 configuration, which became operational at NCEP on 25 February.

Other changes likely for RAPv3, but at this writing not yet fully implemented or evaluated include the following. These are under final evaluation in the RAP-dev cycles running on Zeus, and in summer retrospective experiments.

- Cloud building up to 3000m AGL (from up to 1200m currently) in GSI cloud analysis based on GOES data
- Revised the procedure for obtaining background 2-m mixing ratio for use in computing observation innovations from surface observations in GSI. Currently, the mixing ratio at midpoint (~ 8m AGL) of the lowest model layer is being used. But, since the mixing ratio at 2m is typically higher than that at 8m during the daytime, this procedure (together with our procedure for spreading the surface observation innovations vertically when the background 1-h forecast has a mixed layer) appears to be systematically moistening the atmosphere in the daytime mixed layer. We are testing usage of the model-diagnosed 2-m mixing ratio, or a weighted average of the diagnosed 2-m mixing ratio and the explicitly predicted lowest-model-layer mixing ratio, rather than the lowest-model-layer mixing ratio alone. This is an important change, as it has impact not only at the surface, however, in the lower troposphere where it shows indications of likely reducing a low-level moist bias in the forecast as verified against radiosondes. As noted above, this capability has been introduced, but a final decision on which variant currently under evaluation will be used in RAPv3 has not yet been made.
- Use of new MODIS Leaf-Area Index (LAI) fields in RUC LSM (see Task 3).
- Use of new radar mask to more accurately identifies volumes of atmosphere that are not monitored by radar due to beam blockage by terrain (see MDE January 2014 monthly report).

An initial RAPv3 testing report is available at **http://ruc.noaa.gov/faa-mde/RAPv3-evaluation-15feb2014.pdf**

(Deliverable)

GSD (Haidao Lin) has carried out a significant study on the impact of radiance bias correction for the Rapid Refresh. When implemented, this change will allow the RAP to use satellite radiances more effectively by removing any expected biases by tracking previous biases on a channel-by-channel basis. This report will be included in the next MDE monthly report.

RAP report on satellite assimilation using ensemble/hybrid data assimilation is available at:
http://ruc.noaa.gov/faa-mde/2014_AMS_Lin_EnKF-satellite-assim.pdf

Other activities, some noted more fully under other tasks, also were undertaken:

- Retrospective testing for both RAP and HRRR of the impacts of proprietary in situ tower wind data and other special data under funding from the DOE Wind Forecast Improvement Project was concluded and a report is being written for DOE.
- Discussions with EMC continue concerning the best procedure to ensure that proprietary wind tower and nacelle wind measurements are available to the operational RAP and NAM.
- Quasi-biweekly telecons between GSD and the Storm Prediction Center of NCEP continue to be very beneficial. An example is the November 2013 case noted above.
- Several of GSD's RAP/HRRR developers traveled to Atlanta in early February for the Annual Meeting of the American Meteorological Society. These developers at this collection of meetings presented a total of 17 papers and posters pertaining to the RAP and HRRR.
- On 12 February, Stan, Steve Weygandt and Curtis Alexander participated in the initial telecon of FAA's Numerical Modeling Strategic Planning Team. Stan and Geoff DiMego gave presentations at the subsequent NM SPT meeting on 19 Feb.

NCEP

After a successful decision brief to NCEP Director on the 10th, version 2 of the Rapid Refresh was implemented into NCEP Operations at 12z 25 February 2014. This package, with many improvements to the analysis and model codes, offers significant improvement over version 1, and users are now reaping the benefits. HRRR testing is continuing on WCOSS. EMC has all of the HRRR pieces from GSD in place and has the ability to run the code from end to end. Work is underway to determine how to make the system fit within the one-hour block that each cycle is allotted. IBM analysts have already successfully sped up the forecast job, and work is now underway to speed up the boundary processing and analysis codes. Implementation is still targeted for late July 2014. (Geoff Manikin)
In order to improve support for OPC, the RTMA CONUS domain was expanded westward to cover more of the Pacific Ocean. Files needed for the anticipated HRRR/NAMnest blending that will provide the new first guess for RTMA CONUS were produced. An assessment was made of how to add the HRRR downscaling to the unified smartinit code. While the final downscaling might be included in the operational HRRR package due for implementation in July 2014, the RTMA/URMA developers will still downscale the ESRL version of the HRRR in the meantime to set up their next parallels. NWS Western Region is anxiously waiting for the HRRR/NAMnest-based RTMA/URMA parallels, which are expected to improve the analysis of cold pools. A conference call was held with ESRL to compare observation QC methods used for RTMA/URMA with those of RAP/HRRR, and to discuss the use of new QC methods, for example, ones that do not penalize the observations in regions of complex terrain where the model guidance used for the QC may often be in error (Manuel Pondeca, Steven Levine)

An adjustment has been made to the ceiling height calculation over snowing areas to avoid ceilings that are too high due to too cold air temperature in the SREF members. Unnecessary reads and writes were eliminated in the WRF member's NetCDF I/O with help from IBM. This reduced the amount of I/O by 2/3 in 2/3 of the members and thus improved the efficiency of the SREF [and HRRR] and relieves the demands on the WCOSS file system. The tests of NARRE-TL using RAP V2 input files were successfully completed prior to the RAP implementation. (Jun Du)

The NARRE-TL was tested using the parallel RAPv2 to confirm that after RAPv2 becomes operational, the NARRE-TL will automatically access operational RAPv2 files. An experimental web site for NARRE-TL with parallel RAPv2 results was established. The operational NARRE-TL was compared to NARRE-TL using parallel RAPv2 forecasts for a Jan 5 dense fog case in NY and a Jan 15 dense fog case over VA-DC-MD. The results showed the visibility products from both

ensembles were similar for these two dense fog cases, but the fog product (distinct from the visibility product) showed large improvement in the new NARRE-TL. A review was completed of the 'ceiling' code used exclusively for RAP to produce 'cloud-base height' from the unified post processor versus EMC's ceiling code in the unified post processor. (Binbin Zhou)

The NAMRR has been undergoing numerous upgrades to make its versions of the data assimilation (GSI) source code and model (NMMB) source code consistent with the next NAM implementation. Work continues to make the NAMRR system more general and user-friendly; a version control Trac page has been established for monitoring the project, organizing source code, encouraging collaboration, and maintaining documentation. Work was also completed to enable the initialization of global and regional NMMB ensembles from the global data assimilation system's EnKF members. This is work towards the long or longer-term goal of establishing an NMMB-based EnKF as a part of the NARRE/HRRRE effort. (Jacob Carley)

Work has begun this month on improving the quality control for Level II radial winds from the network of Doppler radars. (Shun Liu)

The convergence problem of regional GSI running with only Mesonet pressure persisted, despite various thinning of the data that were performed to check the results of the minimization. More work is needed to find the reason for the problem. Work continued on using the new ob_type of surface observations without a valid observational pressure. It was coded into GSI to use the temperature and humidity data 2 meters above the model surface. The analysis statistics indicated that this method was no better than locating the data with derived pressure from the standard atmosphere, partly because the model surface height could be very different from the station elevation. The weighting for observations below the model surface was decreased with distance in the GSI. With the new location all the obs would be used with the full weighting since all would be above the model surface. Because of these concerns, the old method of locating observations was kept, using winds 10 m above the model surface and temperature/humidity with derived pressure. Scatter plots were used to adjust the gross error boundaries for the new ob-types. Observational error variances were tuned with adaptive tuning (Desrozier et al), except for 195 and 295 (due to large amounts of data). The impact of the new obs was tested with an off line parallel, and produced neutral/slight-positive impact on short-term NMMB forecasts. The main benefit was that it allows tighter quality control with narrower gross check and less weight with larger observational error to be applied to the data without valid pressure. The final version of GSI is about to be frozen for the NAM upgrade. (Wan-Shu Wu)

CAPS

In February, a new post-doc at CAPS, Dr. Gang Zhao took over the work from Dr. Yujie Pan who returned to her faculty position in China. In Feb., Gang worked with GSD in obtaining accounts on ESRL computers. At the same time, he learned running prior 40km resolution hybrid DA experiments on an NSF supercomputer at the Texas Advanced Computing Center, which can potentially supplement the ESRL machines for larger, higher resolution experiments. CAPS also discussed with GSD scientists at the AMS Meetings on the next phase of tests using the latest version of GSI hybrid and EnKF code base, and a test period from summer 2013. Further efforts will be made to refine the design. Code enhancements made by CAPS to the EnKF and hybrid systems will need to be merged with the latest code base before systematic testing. The goal is to develop and test a dual-resolution hybrid DA system operationally implementable for RAP that couples with RAP's own rather than GFS's EnKF system. CAPS also worked on revising the MWR manuscript on the lower-resolution hybrid DA led by Yujie Pan.

Additional information on RAP-related tasks

ESRL

GSD continues to make pgrb and bgrb files from the ESRL/GSD RAP-primary (RAPv2, but changed to RAPv3 on 12 March) real-time 1-h cycle available from its FTP site for users in NWS and other labs**.**

NCEP

NCEP maintained real-time availability of SAV and AHP guidance to all vendors from the operational hourly RAP on pressure surfaces via the NWS Family of Services (FOS) data feed and via the FAA Bulk Weather Data Telecommunications Gateway (FBWDTG). (EMC&NCO)

NCEP maintained real-time availability of full resolution gridded data from the operational RAP runs via anonymous ftp access via the NCEP server site at **ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/rap/prod/** and at the NWS/OPS site at **ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/** in hourly directories named MT.rap_CY.00 through MT.rap_CY.23. This includes hourly BUFR soundings and output grids, which undergo no interpolation. Both sites now contain only grids in GRIB2 format **http://www.nco.ncep.noaa.gov/pmb/docs/GRIB1_to_GRIB2.shtml.** Gridded RAP and NARRE [-TL] fields are available on **NOMADS** for the CONUS domain on 13 km grid #130 and the Alaska domain on 11.25 km grid #242. RAP fields are also available for the larger North American domain on 32 km grid #221. A limited set of fields from the RAP runs (and other NCEP models) can also be viewed at **http://mag.ncep.noaa.gov**. (EMC&NCO)

Verification of RAP

ESRL's verification of the RAP is available from **http://ruc.noaa.gov/stats**. NCEP maintained its capability and provided access to routine verifications of the operational RAP analyses and forecasts. These include grid-to-station verifications versus rawinsonde, surface, aircraft, Profiler, and VAD data computed periodically at NCEP and accessible via NCEP's Mesoscale Modeling Branch website: **http://www.emc.ncep.noaa.gov/mmb/research/meso.verf.html** .

Deliverables	Delivery Schedule
Task 1 – Improve turbulence guidance from NWP forecasts	
a. Finalize code for RAPv2 for implementation at NCEP (ESRL, NCEP) Vigorous effort leading complete package with extensive improvements, summary at: **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2013.pdf**	Mar 2013 **COMPLETE**
b. Complete the testing of the 40/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data (GSD, CAPS) Initial work completed by CAPS, testing of further enhancements to system. GSD testing and inclusion in RAPv2 of hybrid system with full observational data, using GFS ensemble data. Milestones exceed.	Mar 2013 **COMPLETE**
d. Report on early version of RAPv3 primary cycle at GSD with physics enhancements for initialization of the HRRR. (ESRL) Good progress with revised assimilation and WRFv3.5.1 as reported under Task 1. For more completeness, we request a delay to make this report by 30 January 2014. Complete - **http://ruc.noaa.gov/faa-mde/RAPv3-evaluation-15feb2014.pdf**	**Delay to Jan 2014 COMPLETE**
e. Report on options for including satellite data in the RAP ensemble hybrid data assimilation to ensure overall positive impacts of the data (NCEP, ESRL) Complete - **http://ruc.noaa.gov/faa-mde/2014_AMS_Lin_EnKF-satellite-assim.pdf**	**Delay to Jan 2014 COMPLETE**
f. Finalize RAP version to initialize experimental HRRR for 2014 real-time use toward operational HRRR (ESRL)	Mar 2014
g. Deliver progress report on development of NARRE (NCEP, ESRL)	Mar 2014
h. Deliver progress report on ensemble/hybrid data assimilation for use in NARRE (ESRL, NCEP)	Mar 2014
i. Subject to NCEP Directors' approval, upgrades to observation processing and/or quality control and/or GSI and/or NMMB systems become Operational at NCEP. (NCEP)	Mar 2014
j. Incorporate physics and dynamics improvements from the user community, GSD, and NCEP into WRF for use in the Rapid Refresh system. (NCAR-MMM)	Mar 2014

Task 2: Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE
GSD

In February, a significant work effort was focused on completing the testing and evaluation of updates to the GSD real-time experimental RAP / HRRR system that will be frozen in late March for the 2014 warm season evaluation. The improvements to the RAP are upgrades beyond the RAPv2 that was operationally implemented at NCEP on February 25,

2014, while the changes to the HRRR represent enhancements beyond the represent enhancements beyond the version used for the 2013 warm season evaluation. An extensive package of upgrades was installed, with improvements to many aspects of the RAP model / assimilation system, leading to forecast improvement in many areas.

While all changes contribute to overall forecast improvement, which benefits convection forecasts, key enhancements that improve the RAP storm environment (leading to better HRRR forecasts of convection) include:

GSI Analysis:

- GSI analysis updated to revision 845 (top-of-our-trunk)
- Ensemble KF weights changed to 75%/25% ensemble/static in GSI (from 50%/50%)
- Implemented cycled radiance bias correction for satellite data assimilation
- Three corrections for hydrometeor analysis (theta-v correction, limit of 100% saturation and corrected rain number concentration specification)
- Option for improved forward model (mapping from model background) for dewpoint DA only)

WRF-ARW model:

- WRF model updated to v3.5.1 revision 855
- Switch to GF shallow and deep cumulus scheme including radiation feedback
- Switch to RRTMG shortwave/longwave radiation
- Switch to corrected hypsometric option #2
- RUC LSM updates including revisions to address cold bias over snowpack with
- MYNN planetary boundary layer updates (coupling with GF cumulus scheme, decrease of roughness length over snow.

A set of changes for the HRRR is nearing completion and will be implemented soon. An area of focus for HRRR 3-km assimilation is on the characteristics of the radar reflectivity-based latent heating specification, in particular, the areal extent and magnitude of the heating (controlled by the lower reflectivity threshold for heating specification and the assumed time scale for the heating is applied, respectively). Additional preliminary work has been completed to test application of the hybrid ensemble assimilation for the 3-km HRRR analysis. Assessment of this is ongoing. Real-time production of hourly and 15-min versions the RTMA analysis continue, grids from these analyses available to outside users via the GSD ftp server.

NCEP

NCEP EMC and NCO conducted a planning exercise of what the modeling suite might look like on the Weather and Climate Operational Supercomputing System (WCOSS) Phase 1 (2013-2015) and Phase 2 (2015-2018). The size of the latter would be enhanced by the Sandy Supplemental funds. This plan incorporated ESRL/GSD along with all other contributors to the NCEP Production suite. NWS Director Louis Uccellini was briefed 28 March 2013. There is a risk of delayed delivery of Phase 2 for WCOSS. Initial plans called for an initial HRRR implementation on 65 nodes on Phase 1, but after working for two months with the HRRR package, the HRRR allocation was increased on 11 March to 75 nodes. On phase 2, a HRRR Ensemble (HRRRE), combining multiple runs with configurations of both WRF-ARW and NMMB, is planned. An even more sizable bank of computing was dedicated on Phase 2 to advanced data assimilation for the convective allowing scales of the HRRRE, likely involving a 4-dimensional version of the current GSI-hybrid-EnKF.

Deliverables	**Delivery Schedule**
Task 2 – Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE	
a. Report on initial tests of 3-km 15-min RTMA cloud / surface analysis for use in frontal diagnostics, CI assessment and other near-surface assessments (ESRL, NCEP) *Good progress toward 3km RTMA and RUA surface and cloud analyses* *Successful initial tests summarized in report:* **http://ruc.noaa.gov/pdf/GSD_RTMA_report.pdf**	Feb 2013 **COMPLETE**

Deliverables	Delivery Schedule
b. Incorporate all assimilation and model changes that affect the HRRR into a frozen version of HRRR (and parent Rapid Refresh) for 2013 real-time use (ESRL) *Extensive set of enhancements in place and running in real-time experimental GSD RAPv2 / HRRR system*	Mar 2013 **COMPLETE**
c. Provide preliminary 15-min RTMA surface analyses as experimental improved basis for frontal diagnostics and other diagnostics from surface analyses (ESRL, NCEP) **Prototype HRRR-based 15-min RTMA analysis completed with sample grids and graphics.**	Aug 2013 **COMPLETE**
d. Report on computing resource status on NCEP Central Computing System, NOAA R&D Site A and NOAA R&D Site B with regards to possible implementation of HRRR (NCEP, ESRL) See above discussion concerning ~2014 implementation and Task 4	**June 2013** **COMPLETE**
e. Complete FY13 internal assessment with revised 3-km HRRR running every hour (ESRL) **Assessment complete with very good results seen for 2013 HRRR in objective and subjective verification and high run reliability**	Sept 2013 **COMPLETE**
f. Provide revised 15-min RTMA surface analyses as primary basis for frontal diagnostics and other diagnostics from surface analyses for real-time use in 2014 (ESRL, NCEP). **Real-time 15-min RTMA running with grids available on ftp**	Feb 2014 **COMPLETE**
g. Finalize all changes to the HRRR for real-time use in 2014 (ESRL) Good progress with major change bundle in place	Mar 2014

Task 3: Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

GSD

The RAPv2 physical parameterization configuration resulting from test and evaluation of physics options during the late 2012 – early 2013 period and described in previous reports was part of the RAPv2 implementation on 25 February 2014:

- New 9-level configuration of the RUC land-surface model (RUC LSM) with fix to canopy evaporation when the MYNN surface layer is used.
- Mellor-Yamada-Nakanishi-Niino (MYNN) planetary-boundary- and surface-layer scheme (modified considerably by Joe Olson) in place of the Mellor-Yamada-Janjic (MYJ) scheme used in RAPv1.
- Continue use of the Grell G3 scheme from WRFv3.2.1.
- Continue use of the Goddard short wave and RRTM long-wave radiation schemes.
- Use WRFv3.4.1 version of the Thompson microphysics.

Looking toward a mid-late March code freeze for the RAPv3 and HRRRv2 for summer 2014, intensive effort continued in February toward arriving at the final version of the RAPv3 physics configuration. At this writing, the physics suite for the March code freeze is essentially set. Below are listed the main features of this suite and significant changes from RAPv2.

- Long and short wave versions of RRTMG. In addition to provision for attenuation of solar radiation by aerosol, RRTMG has a more rigorous accounting for the attenuation of solar radiation by ice and snow recently developed by Greg Thompson. Although RRTMG has available a semi-empirical diagnostic cloud fraction calculation, an alternative, being examined by Joe Olson, is direct coupling with the shallow convection component of the Grell-Freitas convection (see below). Because the RRTMG is more expensive, it will be called every 20min instead of every 10. Compensating for this, the "swint" option in the WRF model namelist (available with the recent WRFv3.5.1) has been activated, so that at each time step in which radiation is not called; the incoming solar radiation is adjusted to correspond to the current solar zenith angle.
- RUC LSM (9-level version) changes. These include 1) treatment of albedo in situations of partial snow cover, which itself must be parameterized, 2) reduction of surface roughness in areas of snow cover over tundra, scrubland

and cropland (earlier testing on this was mostly done with the MYJ PBL and surface layers (see further discussion below), 3) further consideration of the representation of snow melt in low-level warm-advection conditions typical of spring. During February, retrospective experimentation and real-time evaluation produced a significant reduction of the cold bias over snow (see below). In addition, Tanya Smirnova has obtained MODIS satellite-derived leaf-area index (LAI) fields to be made available with the WRFv3.6 release, and is evaluating the impact of these fields relative to the current specification of leaf-area index in the RUC LSM.

- Further upgrades to the MYNN surface and boundary layer schemes. See further discussion below on this. These are intended to address two systematic biases that were not completely eliminated in RAPv2: the nighttime cold bias over snow cover noted above in conjunction with the RUC LSM, and the daytime warm and dry bias at the surface we see with the RAPv2 under clear skies, particularly during the warm season. Of the two, the cold bias over snow is the most egregious and received the most attention during February.
- Replacement of the G3 convection scheme used in RAPv1 and RAPv2 by the Grell-Freitas deep and shallow scheme. As indicated in the January report, the G-F deep convection scheme is performing well. However, further testing of the scale-aware aspects of the shallow scheme at cloud-permitting resolutions has yielded unsatisfactory results so far. Further development and testing of this scheme will be necessary before it can be considered suitable for the HRRR.
- Continued use of the NCAR Thompson microphysics. This continues to work well in the context of other changes for RAPv3.

Ongoing physics-related efforts to further improve the current RAPv3 model performance center on 2-m temperature forecast biases that involve the interplay between the RUC LSM, the MYNN surface and boundary-layer scheme and, in the case of the warm bias, the parameterized convection.

- To overcome a stubborn nighttime cold bias in 2-m temperature over snow cover we are decreasing surface thermal roughness over snow cover to decrease coupling of the atmosphere close to the ground with the ground itself, and under very stable conditions increasing the mixing within the atmosphere itself. But, the most effective change toward reducing the cold bias has been to increase the thickness of the top layer of snow.
- To reduce the surface warm bias over land under clear skies in daytime, most evident in the warm season and discussed in previous MDE reports, we have switched to the RRTMG scheme with its improved accounting for attenuation of solar radiation by (climatological) aerosol and parameterized moist convection through an empirical relative-humidity / fractional-cloud relationship.

Further activities:

- New aerosol-aware microphysics from NCAR. On 15 Feb, Greg Thompson notified GSD that the new aerosol-aware microphysics from NCAR is available as part of the WRFv3.6-pre-release. (The official WRFv3.6 release will come in April.) We anticipate significant testing of the aerosol-aware microphysics to begin once the RAPv3 / HRRR configuration is frozen in late March or early April, toward NCEP implementation in the 2015 (perhaps spring) ESRL versions of the RAP and HRRR.

NCEP

IBM analyst examining the HRRR prediction model determined that the microphysics was the piece consuming the largest amount of resource, but the focus has shifted to speeding up GSI or the overall I/O. This remains a possible area for further improvement in speed if someone with the expertise could look into the code. Neither IBM nor EMC have that expertise. (DiMego)

NCAR/RAL

CURRENT EFFORTS: A few minor adjustments were made to the aerosol-aware Thompson and Eidhammer (2014) microphysics scheme based on additional testing. The changes are part of the final preparation for release in the public version of WRFV3.6 coming in April 2014. Also, we delivered a report on various WRF physical parameterizations improvements and additions performed during 2013.

FUTURE EFFORTS: NCAR-RAL will assist NOAA-GSD to adopt/utilize the new scheme. NCAR-RAL and NOAA-GSD still need to plan and carry out a method to link aerosols/species found in WRF-RAP-Chem to simplify into those variables used by the new microphysics scheme; or, alternatively, use with built-in climatological aerosols

PROBLEMS/ISSUES ENCOUNTERED: The integration of the aerosol-aware microphysics scheme depends on availability of NOAA-GSD and NCAR-MMM personnel and a timeline of activities has not yet been decided.

INTERFACE WITH OTHER ORGANIZATIONS: None.

NCAR/MMM

Deliver a WRF Users' Workshop and WRF Tutorial for the User Community

NCAR gave a WRF tutorial at the University of New South Wales in Sydney, Australia on Feb. 24–27. This covered the basic WRF system, included practice sessions, and was followed by a WRF workshop. There were 63 tutorial attendees.

PLANNED EFFORTS: NCAR will begin organizing the next WRF Users' Workshop in Boulder in March. The workshop is scheduled for June 23–27, 2014.

UPDATES TO SCHEDULE: NONE

Incorporate Physics and Dynamics Improvements into WRF

NCAR led the oversight of preparations of the next major release, WRF V3.6. NCAR held regular meetings of the Release Committee. The second friendly user release will be in early March. The V3.6 release is targeted to be in the first half of April, and details on it may be found at: **http://wrf-model.org/users/release.php**.

Jimy Dudhia (NCAR/MMM) consulted with A.-J. Deng and Dave Stauffer (Penn State) on their testing of the PSU shallow convection scheme. Deng and Stuaffer are doing case studies as part of this, and they identified problems related to non-repeatable results. The PSU shallow convection scheme will not be in V3.6, but it is a candidate for future WRF releases.

Dudhia worked with Ming Chen (NCAR/MMM) in the preparation of codes for the V3.6 release. They are setting up the system to have the new lake model for WRF work with a WPS-provided lake mask. They also obtained lake depth data for to enable WPS to prepare WRF for the lake model.

Dudhia worked with Stefan Tulich (NOAA) in resolving issues with conservation in the WRF vertical diffusion formulation. The scheme currently uses mu in calculations, although it should more accurately use density. This change will eventually be released, although most likely not until WRF V3.6.1.

Dudhia consulted with Pedro Jimenez (CIEMAT, Spain) in evaluating WRF surface winds against ocean wind site data. The observational comparisons found different PBL schemes to have similar biases, and they believe the problem lies in the surface roughness formulation. They are continuing to investigate improvements to the surface stress formulation to reduce the wind biases.

PLANNED EFFORTS: NCAR will issue a second friendly user release prior to the official release of WRF V3.6. The development and incorporation of new physics and dynamics for WRF for the RAP and HRRR will continue through this quarter.

UPDATES TO SCHEDULE: NONE

Deliverables	**Delivery Schedule**
Task 3 – Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE	**Delivery Schedule**
Conduct initial single test of aerosol-aware microphysics in ARW in a RAP configuration as start of a 2014 evaluation for its suitability as part of the RAPv3 prototype for 2015 NCEP implementation (NCAR-RAL, ESRL) This task name has been changed to accurately reflect the long-term evaluation needed for this complicated change over much of 2014.	Feb 2014. Task name changed.
b. Final model physics code transfer complete to EMC for Rapid Refresh 2 upgrade change package to be implemented at NCEP by spring 2014 (ESRL, NCEP)	Mar 2013 **COMPLETE**

Freeze of model physics code for March 2013 version of RAP at ESRL allows this milestone to be met.	
c. Pending NCEP computer readiness and EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh v2 software to NCO (NCEP, ESRL)	**Sept 2013 COMPLETE**
d. Transfer upgraded coupled aerosol-microphysics scheme into a test version of HRRR (NCAR-MMM, ESRL) COMPLETE – 15 Feb 2014 – see report above - RAL has made available aerosol-aware microphysics to GSD.	Dec 2013 **COMPLETE**
f. Finalize microphysics changes and other physics changes to improve icing forecasts for ESRL version of RAP and HRRR for 2014 real-time use (ESRL)	Mar 2014
g. Report summary of icing probability skill measures by quarter for the year. (NCEP)	Mar 2014

Task 4: Develop convection-ATM-specific improvements for guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA

Task 4 – Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2013 real-time use (ESRL)

Current:

A retrospective period from 15-31 May 2013 has been established for evaluation of model and data assimilation changes for the 2014 version of the ESRL RAP and HRRR. A control run for the retrospective period was completed using the 2013 ESRL RAP and HRRR versions but also included an adjustment in soil temperature and moisture and a correction in the RUC land surface model to remove unrealistic surface evaporation flux in areas of precipitation that were not available during the real-time runs in early May 2013. The code for the WRF-ARW version 3.5.1 update including changes to the Thompson microphysics scheme and associated reflectivity, VIL and echo top diagnostics has been merged with the ESRL RAP and HRRR WRF-ARW code base. RAP retrospective runs with WRF-ARW version 3.5.1 and data assimilation changes have been completed for the May 2013 period along with an upper-level and surface forecast verification comparison to the control run. The experiments include new convective parameterization and radiation schemes and updates to the boundary layer and land-surface schemes with forecast improvements noted in the results when compared to the control run. A preliminary HRRR retrospective run has been executed including most of the WRF-ARW version 3.5.1 model changes for the HRRR and using the RAP retrospective run for initial and boundary conditions. The reflectivity forecast verification was executed for this HRRR retrospective run with preliminary results showing nearly identical CSI (critical success index) values with an improved (reduced) bias noted at nearly all lead times when compared with the control run.

Planned:

Evaluation of additional ESRL RAP and HRRR model and data assimilation changes will be conduced using the 15-31 May 2013 retrospective period. These additional HRRR retrospective runs will focus on data assimilation changes within the HRRR including improved retrievals of rain, snow and graupel hydrometeors and inferred latent heating from radar reflectivity observations. Once the RAP changes are finalized, the final HRRR retrospective run will be executed including an evaluation of the associated reflectivity, VIL and echo top diagnostics for 2014 configurations of the ESRL RAP and HRRR.

Task 4 – Assess HRRR reliability and provide monthly reporting (ESRL)

HRRR Reliability for 0-8 Hour VIL/Echo Tops for February 2014

Jet
All runs: 98.4%
3 or more consecutive missed runs: 99.6% (most meaningful for CoSPA)
6 or more consecutive missed runs: 100.0%

1 outages of at least 3 hrs. or longer
0 outages of at least 6 hrs. or longer

Zeus
All runs: 0%
3 or more consecutive missed runs: 0% (most meaningful for CoSPA)
6 or more consecutive missed runs: 0%
1 outages of at least 3 hrs. or longer
1 outages of at least 6 hrs. or longer

Combined (Jet or Zeus)
All runs: 98.4%
3 or more consecutive missed runs: 99.6% (most meaningful for CoSPA)
6 or more consecutive missed runs: 100.0%
1 outages of at least 3 hrs. or longer
0 outages of at least 6 hrs. or longer

****** NOTE: During February Zeus was used extensively for HRRR development testing and not as a backup capacity.***

Under Task 4 – Complete implementation of refined cloud-top cooling (SatCast) assimilation for HRRR for real-time use in 2014

Tracy Smith continued her work with the assimilation of GOES-CI cloud-top cooling radar data within the RAP. Following her initial experiments she has completed an additional retrospective experiment using a higher cooling rate threshold and successfully removed some of the false alarms (see Fig. 1 below), resulting in slight higher skill scores. Additional experiments are ongoing.

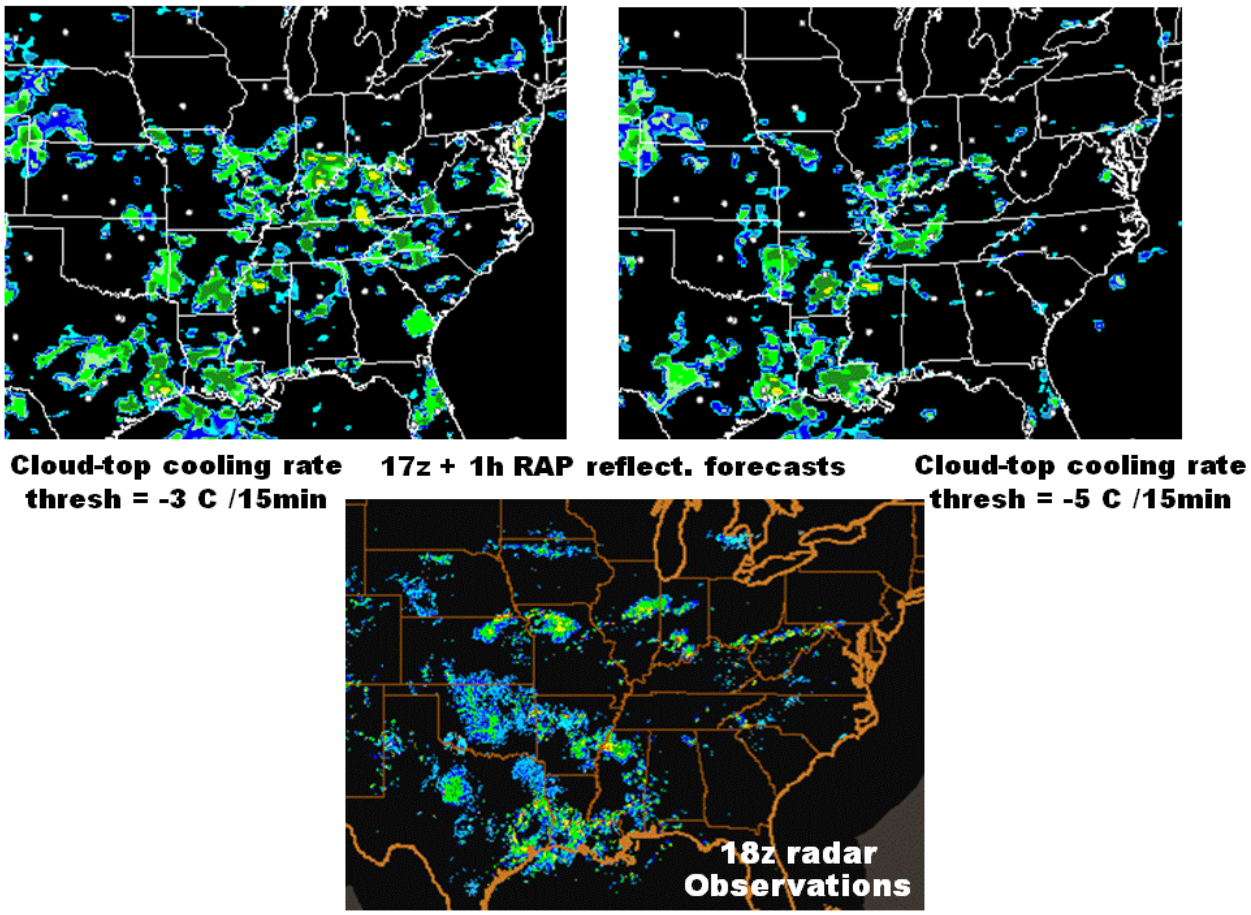

Fig. 1, Comparison of RAP 1-h forecasts valid 18z 8 July 2012 with assimilation of satellite-based cloud-top cooling rate data using a minimum threshold a -3 deg. C per 15 min. (left) and -5 deg. C per 15 min (right). Comparison with the radar observations (bottom) illustrates the reduction in spurious convection associated with the more restrictive -5 deg. threshold (right).

Also Under Task 4 – Interact with CoSPA (or other) program partner labs and the FAA

Team (ESRL/GSD, NCAR/RAL, and MIT/LL) telecons and e-mail correspondence will continue to occur during the CoSPA offseason regarding upcoming HRRR changes. A CoSPA planning telecon was conducted on 11 February 2014 with MIT/LL, NCAR and the FAA sponsor to discuss the upcoming changes to the HRRR model prior to the 01 April 2014 CoSPA demonstration start. This discussion included both ESRL RAP and HRRR data assimilation and model changes. Additionally, HRRR model output format changes were discussed that will require a change at NCAR for CoSPA blending. A follow-up planning telecon was scheduled for 10 March 2014 to provide more detailed information regarding the upcoming HRRR changes. Discussion with MIT/LL continues regarding possible collaboration on convective weather avoidance polygons including the potential for feedback on the evolution of the size distribution of forecasted convective structures in the HRRR.

Deliverables	**Delivery Schedule**
Task 4 – Develop convection-ATM-specific improvements to guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA	
Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2013 real-time use (ESRL) Code for revised echo-top / reflectivity diagnostics with revised microphysics implemented in GSD real-time HRRR.	Mar 2013 **COMPLETE**
Conduct baseline testing of the early 2013 HRRR version (ESRL) Baseline testing of 2013 HRRR version completed as part of code preparation for freeze. Summary of skill score improvements being prepared.	Mar 2013 **COMPLETE**
Report on evaluation of new microphysics scheme and associated echo-top and reflectivity diagnostics in ESRL/GSD RAP and HRRR (ESRL) *Preliminary evaluation completed and summarized in report:* **http://ruc.noaa.gov/pdf/GSD_reflectivity_report.pdf**	Mar 2013 **COMPLETE**
Assess HRRR reliability and provide monthly reporting (ESRL) Reliability statistics are being reported each month	*Apr 2013* **COMPLETE** *(ongoing)*
Report on evaluation of revised WRFv3.5.1 microphysics for RAP/HRRR for its effects on echo-top and reflectivity in ESRL RAP/HRRR (ESRL)	Mar 2014 **Good progress**
Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2014 real-time use of HRRR (ESRL)	Mar 2014 **Good progress**
Complete implementation of refined SatCast assimilation for HRRR for real-time use in 2014 (ESRL) **Evaluation of preliminary results**	Mar 2014 **Good progress**
Report on 2014 baseline testing of the HRRR (ESRL)	Mar 2014